

**APPARATUS FOR DETERMINING AND/OR MONITORING A PROCESS  
VARIABLE**

The invention relates to an apparatus for determining and/or monitoring a  
5 process variable of a medium. The apparatus includes an oscillatable unit  
secured to a membrane, and a sending/receiving unit, which excites the  
membrane and the oscillatable unit to oscillate and which receives the  
oscillations of the oscillatable unit, with the sending/receiving unit comprising a  
10 disk-shaped, piezoelectric element. The apparatus further includes a  
control/evaluation unit, which monitors and/or determines the process variable  
on the basis of the oscillations of the oscillatable unit. The process variable is,  
for example, the fill level, density or viscosity of a medium.

Apparatuses having at least one oscillatory element, so-called vibration  
15 detectors, are already known for detecting, or monitoring, the fill level of a fill  
substance in a container. The oscillatory element is usually at least one  
oscillatory rod, which is secured to a membrane. The membrane is excited to  
oscillate via an electromechanical transducer, e.g. a piezoelectric element.  
Because of the oscillations of the membrane, also the oscillatory element  
20 secured to the membrane oscillates.

Vibratory detectors embodied as fill level measuring devices make use of the  
effect wherein the frequency and amplitude of the oscillations depend on the  
current degree of covering of the oscillatory element - while the oscillatory  
25 element can oscillate in air freely and without damping, it experiences a  
frequency and amplitude change, as soon as the fill substance rises to cover it  
partially or completely. On the basis of a predetermined frequency change  
(usually, the frequency is measured), an unequivocal deduction can then be  
drawn concerning the reaching of a predetermined fill level of the fill substance

in the container. Fill level measuring devices are primarily used as protection against overfilling or for the purpose of protecting against pumps running empty.

The damping of the oscillation of the oscillatory element is also influenced by the present density of the fill substance. Therefore, at constant degree of covering, there is a functional relationship with the density of the fill substance, so that vibration detectors are best suited both for fill level, and also for density, determination. In the practice, for the purposes of monitoring and detecting fill level, or density, of the fill substance in the container, the oscillations of the membrane are registered and converted by means of at least one piezoelement into electrical, received signals. The electrical, received signals are then evaluated by an evaluation electronics. In the case of fill level determination, the evaluation electronics monitors the oscillation frequency and/or the oscillation amplitude of the oscillatory element and signals the state 'sensor covered', or 'sensor uncovered, as soon as the measured values, respectively, fall below, or exceed, a predetermined reference value. A corresponding report to the operating personnel can occur optically or acoustically. Alternatively or supplementally, a switching event is triggered; thus, perhaps, an inlet, or outlet, valve on the container is opened or closed.

DE 100 22 891 discloses an extremely advantageous variant of a sending/receiving unit, via which, on the one hand, the membrane of a vibration detector is excited to oscillate, and via which, on the other hand, the oscillations of the membrane are registered and converted into electrical signals. In each case, two sending and receiving electrodes are provided, which are, essentially, 90°-circular segments and are arranged on the same side of a disk-shaped, piezoelectric element. The piezoelectric element itself is homogeneously polarized and has a circular cross section. An inverter is provided for driving the piezoelectric element.

An object of the invention is to improve the structure of an apparatus for determining and/or monitoring a process variable in such a manner that the construction and circuit effort is as small as possible.

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The object is achieved by the following features: That the disk-shaped piezoelectric element has at least two segments, which are polarized essentially oppositely to one another, and that, on the side of the disk-shaped piezoelectric element facing away from the membrane, at least two electrodes of opposite polarity are applied. The piezoelectric element thus has two segments, which are oppositely polarized to one another. The direction of the polarization should, however, be essentially perpendicular to the membrane. Furthermore, these segments are connected with electrodes, which are of different polarity. A result of this is that the application of an alternating voltage to the electrodes leads in the segments, in each case, alternately, to a shortening and an increasing of the layer thickness of the piezoelectric element. Electrically, the segments are thus connected in series. The great advantage of this is that the piezoelectric element must only be contacted on one side; thus, no electrodes have to be brought to, and connected with, the underside of the piezoelectric element (i.e. to the side of the piezoelectric element facing the membrane). This is, above all, important, when the apparatus has very small dimensions, so that only very little space is present for the running of conductors.

25 An advantageous embodiment provides that exactly two electrodes of opposite polarity are applied to the side of the disk-shaped piezoelectric element facing away from the membrane. This embodiment is minimal with respect to execution and costs. Associated therewith is the fact that the piezoelectric element only has two segments, which are polarized essentially oppositely to

one another. Advantageously, the electrodes are located exactly above the segments and also, in each case, electrically conductively connected only with one segment.

An embodiment includes that the elements are essentially of equal shape.

- 5 Such a symmetric embodiment has the advantage that a wrong contacting is not possible. Furthermore, in this way, in each case, equally large regions of the piezoelectric element are excited to oscillate.

- 10 An embodiment provides that the electrodes have the shape of semicircular segments. This is a special embodiment of the symmetric construction, with this structure also being kept for the application of two electrodes.

- 15 An embodiment includes that the electrodes are so structured and arranged that one annularly surrounds the other. This embodiment can also be applied in the case of more electrodes. Preferably, one electrode is a circle (thus it is an annular ring whose radius of the smaller/inner circle is zero) located in the middle of the piezoelectric element and surrounded annularly by the remaining electrode or electrodes.

- 20 An embodiment provides that the piezoelectric element is provided on its side facing the membrane, at least partially, with a conductive coating. Additionally, an embodiment includes that the side facing the membrane is connected electrically conductively with ground. In this way, the electric connection of the segments of the piezoelectric element in series is obtained. Depending on the  
25 embodiment of the apparatus, the side facing the membrane can also be connected directly conductively with the housing.

The invention will now be explained in greater detail on the basis of the appended drawings, the figures of which show as follows:

Fig. 1 a schematic drawing of the apparatus of the invention;

Fig. 2 a section through the apparatus of the invention; and

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Figs. 3a, 3b and 3c top views onto the piezoelectric element.

Fig. 1 shows a schematic drawing of the apparatus of the invention for determining and/or monitoring a process variable of a medium (not shown) in a container (not shown). The process variable can be the fill level, density or viscosity of the medium. The apparatus has an essentially cylindrical housing. On the lateral surface of the housing, there is a screw thread for securing the apparatus. Secured to the membrane 5 of the apparatus 1 is the oscillatable unit 1 protruding into the container. In the illustrated case, the oscillatable unit 1 is embodied in the form of a tuning fork; thus the tuning fork includes two oscillatory rods 3, 4 secured to the membrane 5 and protruding into the container. A sending/receiving unit 6 causes membrane 5 to oscillate, with the sending unit exciting the membrane 5 to oscillate with a predetermined transmitting frequency and the receiving unit receiving the response signals of the oscillatable unit 1. Due to the oscillations of the membrane 5, the oscillatable unit 1 also oscillates, with the oscillation frequency being different when the oscillatable unit 1 is in contact with the fill substance and a mass-coupling to the fill substance is present, compared with when the oscillatable unit 1 can oscillate freely and without contact with the fill substance.

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Piezoelectric elements change their thickness as a function of a voltage difference applied in the direction of polarization. If an alternating voltage is applied, then the thickness oscillates: If the thickness increases, then the diameter of the piezoelectric element decreases; if, on the other hand, the

thickness decreases, then the diameter of the piezoelectric element increases correspondingly. Due to this oscillatory behavior of the piezoelectric element 15, the voltage difference effects a flexing of the membrane 5 clamped into the housing. The oscillatory rods of the oscillatable unit 1, since they are arranged  
 5 on the membrane 5, oscillate with opposite phase about their longitudinal axes, due to the oscillation of the membrane 5. The received electrical signals are evaluated by the control/evaluation unit 10.

Fig. 2 shows a section through the apparatus. Shown is the piezoelectric  
 10 element 15 with the segments 18 illustrated here, which are polarized in opposite directions relative to one another (see the arrows indicating the directions of polarization). On top of the segments, on the side of the piezoelectric element 15 facing away from the membrane, are the electrodes 20, which have different polarity (- and +). Due to the different directions of  
 15 polarization of the segments 18, and the signs of the electrodes 20, an alternating current leads to an alternating thickness change of the piezoelectric element. The side 17 of the piezoelectric element 15 facing toward the membrane can be connected electrically conductively with the housing and, thus, with ground, or, when a galvanic separation is necessary, also an  
 20 insulating layer can be placed between the piezoelectric element 15 and the membrane 5. For a contacting of the side 17 facing the membrane, it is also possible to contact around a section of the piezoelectric element 15, and, consequently, the connection with ground can be effected via this section.

25 Figs. 3a to 3c show two embodiments of the side of the piezoelectric element facing away from the membrane (Figs. 3a and 3c) and one embodiment of the side facing toward the membrane 5 (Fig. 3b). The piezoelectric element 15 itself is, in each case, preferably circularly shaped. Fig. 3a shows a variant, in which two electrodes 20 are applied, which are essentially semicircularly

shaped. Between the electrodes, an insulating layer 21 is applied, so that the electrodes 20 are not short circuited. In Fig. 3c, one electrode 20 is circularly shaped, or this electrode is annularly formed, with its radial thickness being equal to the radius of the outer circle, and the other electrode is annularly  
5 formed. Also here an insulating layer 21 is located between the electrodes. Fig. 3b shows the membrane-facing side, which is preferably connected with ground, in order to effect a series connection of the segments of the piezoelectric element. On the membrane-facing side, a conductive layer 25 is applied. For example, layer 25 is of metal. This embodiment of the membrane-facing side  
10 can thus be combined with both the variant of Fig. 3a, as well as with that of Fig. 3c, of the other side.

## LIST OF REFERENCE CHARACTERS

	1	oscillatable unit	
5	5	membrane	
	6	sending/receiving unit	
	10	control/evaluation unit	
	15	piezoelectric element	
	16	side of the piezoelectric element facing away from the membrane	
10	17	side of the piezoelectric element facing the membrane	
	18	segment of the piezoelectric element	
	20	electrode	
	21	insulating layer	
	25	conductive	layer